Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE BODY SENSE HAIRS OF LEPIDOPTEROUS LARVÆ.[1]

WILLIAM A. HILTON.

It is well known that, as a rule, all arthropods have their bodies and appendages clothed with hairs, or setæ, which are simply modified parts of the cuticle.

These hairs vary in form and in structure. In the most common type the hair is hollow, and its lumen communicates with the body cavity by means of a "pore canal" in the cuticle (Fig. 1). Through this pore various structures may extend into the lumen of the hair, as a prolongation of a hypodermal cell, gland ducts, and nerves.

There are published references to solid hairs of insects; but if we except certain minute elevations of the cuticle, such as are represented in Fig. 2, and which are more or less hairlike, I found none in the insects studied. It should be said, however, that certain scalelike appendages of the cuticle of the larva of Corydalis (Fig. 3, *h*) appear to be solid; but as these occur, each at the end of a pore canal, they may prove to be hollow.

The most commonly observed structure that passes through the pore canal into a hollow hair is a prolongation of a hypodermal cell, which is much larger than the ordinary cells of the hypodermis (Fig. 4, *t*). Such a cell was named a "trichogen," by Graber, as it is believed to be the element that produces the hair. In many cases there are associated with the trichogen one or more gland cells, which discharge their secretion through the hair; the stinging hairs of certain larvæ are examples of this type. Such hairs may also have a nerve extending to them, and perhaps they always do.

A type of hollow hair which occurs much more commonly than does the glandular hair is one into the lumen of which there extends only a trichogen cell and a nerve. The larger number of the organs of special sense of arthropods are hairs of this type, more or less modified. Frequently, however, the modification has been carried so far that the organ of special sense is not at all hairlike. This is especially true of many of the supposed organs of taste and of smell. I have made no attempt to study these.

---

[1] *Contribution from the Entomological Laboratory of Cornell University.*

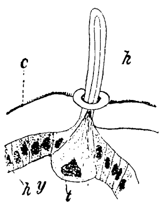

FIG. 1. — Simple hair from the silkworm (*Bombyx mori*).

The investigation, the results of which are given in this paper, was confined to a study of those hollow hairs, or setæ, which are distributed over the surface of the body and are believed to be organs of touch. The primary object of this investigation was to determine as definitely as possible just what type of hair on the body surface is a sense hair; a secondary object was to determine in what ways this type is modified in various lepidopterous larvæ. Some work was also done on several other orders of insects, with the result that a close correspondence was found in the structure of these hairs among even widely separated orders.

METHODS.

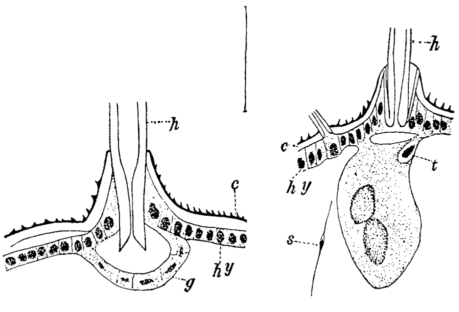

FIG. 2. — Sections through hairs from a tiger moth (*Spilosoma virginica*).

In order to definitely demonstrate which hairs were sensory it was necessary to have recourse to special histological methods, as the terminations of the nerves for touch in insects are exceedingly delicate, and the usual microscopical methods are entirely inadequate for the successful differentiation of the nervous tissues. For general anatomy of the sense hairs the usual fixing and staining fluids were used; but for staining the peripheral nerve fibers and cells the *intra vitam* methylen blue method was found to be especially useful; and, as the larger part of the work was based upon results thus obtained, it may be well to give the exact method of procedure.

The fluid used for injecting was Grübler's B.x methylen blue, $\frac{1}{2}$ per cent solution in normal salt. The injection by means of a small syringe was made usually in the side, back of one of the last abdominal segments, and enough liquid was injected to color the segments near the head, care being taken to insert the canula only under the hypodermis and muscles, and not into the alimentary canal.

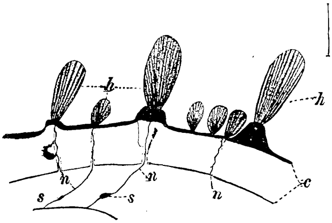

Fig. 3. — Section of cuticle of *Corydalis cornuta*, showing large and small flat scales supplied with nerves and cells. All beyond edge of cuticle from Golgi preparation, the sensory cells and nerves demonstrated by methylen blue.

After injection the animal was left quiet for a period of about three hours for most insects, but with some, as with Pieris, two hours was a better time, and four hours seemed to be best for Datana larvæ. It is important that the insect remain alive during this period after injection.

When the proper period has elapsed the nerves and nerve cells should be well stained and almost all other tissues free from stain. After successful staining the specimen is cut open lengthwise and pinned out over a hole cut in sheet cork, the muscles and viscera are removed by careful dissection, and then, on examining under a microscope, the nerves and nerve cells are seen stained upon the surface of the unstained hypodermal layer. The bases of the hairs may be seen through the hypodermis, and it is easy to trace nerve cells and fibers in connection with them. By keeping the preparation wet with normal salt solution and using different powers of the microscope, much may be learned regarding the structure and distribution of the peripheral nervous system without further preparation; for this work the silkworm (*Bombyx*

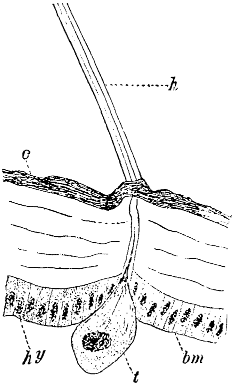

Fig. 4. — Section of hair of Datana.

mori) was very good, because the blue nerves on a pure white background stand out very clearly. Of course, such preparations last but a short time, fading out in an hour or less, and the ultimate distribution of the terminal nerve fibers cannot be seen without sectioning.

The following modification of Bethe's formula for fixation was used :

Ammonium molybdate	1 g.
Con. HCl	10 drops.
Dist. H_2O	100 cc.

This solution was used ice cold and allowed to act on the tissues from eight to twenty-four hours, after which they were washed well in cold distilled water and placed in absolute alcohol for about three hours, then cleared in xylene, and either mounted whole or imbedded and sectioned.

HISTORICAL.

Setiferous sense organs in arthropods were described by many early workers ; but the first description of a bipolar nerve cell one termination of which was at the base of the hair and the other continued with the nerve trunk to the central nervous system was made by Leydig in 1851, for certain hairs of *Corethra plumicornis*. This discovery of Leydig was verified, and the form described is now generally regarded as the type of sensitive termination in arthropods. Leydig undoubtedly mistook the trichogen cells for nerve cells ; these two elements were later distinguished by Hauser (**'80**) and Villanes (**'81**). Later works, especially of Retzius (**'90–'95**) and Vom Rath (**'91–'96**), brought forth the following results :

In arthropods all sensory terminations, the eyes excepted, are in hairs. To each hair there corresponds at a greater or less distance from the base one or more bipolar sense cells, of which the distal prolongation penetrates into the interior of the hair terminating without ramifying, the other prolongation (proximal) in a nervous center. These observations, which accord so well with other classic works on the peripheral nervous system, were made somewhat doubtful by more recent works.

In Crustacea, Bethe ('95) and Nusbaum ('97) recognized the sensory neuron as a bipolar cell, the distal portion penetrating the hair without ramifying and the other prolongation continuing with the nerve trunk; but, at the same time, they also described a plexus of cells, — not a system of neurons, but a true plexus. Bohumil Nemec ('96) found in certain isopods a system of peripheral ganglia. These ganglia are centers of a hypodermal plexus compared by him to the plexus of Bethe. Rina Monti ('93) described a similar plexus in insects, and Holmgren ('96) described and figured such a network of multipolar cells with their processes in the larva of a sphinx moth.

In '97 and '98 Duboscq summarized very well the results of many authors and added some of his own observations on Orthoptera and chilopods. He used both the Golgi method and methylen blue and discredits much of the former work on the nerve plexus obtained by methylen blue, and that on the termination of the nerves by the Golgi method.

SENSORY CELLS AND NERVES OF BODY SENSE HAIRS.

Following the sensory nerve trunks peripherally, they are seen to run straight out from the central nervous system, dividing dichotomously, most of the branches coming off when the region of the back is reached. After a number of divisions, small nerves from bipolar nerve cells join the larger trunks, and the peripheral parts of the larger nerves may also be traced to bipolar nerve cells (Fig. 5).

In the silkworm (*Bombyx mori*) bipolar nerve cells are spindle-shaped and have a very dark nucleus, which in many cases nearly fills the cell body (Figs. 5–6). In most forms studied the cells are more nearly spherical, but yet not markedly so (Figs. 5–6). As a general rule the sensory cell is quite a distance from its hair, but again in the myron sphinx there is a slight variation, the nerve cell being at the edge of the pore canal, almost in its cavity; this may not indicate that the nerve is really shorter, but only apparently so, because of the thickness of the cuticle and consequent length of the pore canal.

The prolongation of the nerve just beyond the sense cell is of considerable thickness, staining deeply; and abruptly after this the nerve extending to the hair is very minute.

It was impossible to trace the nerves farther than the bases of the hairs where whole mounts were made, and Duboscq ('97 and '98), in Orthoptera and chilopods, traced the nerves only this far. However, earlier workers with methylen blue who studied simply the surface views represent nerves coming from the tips of the hairs; but it seems probable that such figures are in large part diagrammatic. Vom Rath found by the Golgi method cavities of sensory hairs filled with nerves; this result is regarded as an artifact by Duboscq, who shows clearly how appearances like nerves may be obtained in the cavity of hairs due to deposits of chromate of silver; and he shows quite clearly that when nothing but the nerve cell and fiber is impregnated the nerve fiber stops at the base of the hair, as was apparently the case in his methylen blue preparations.

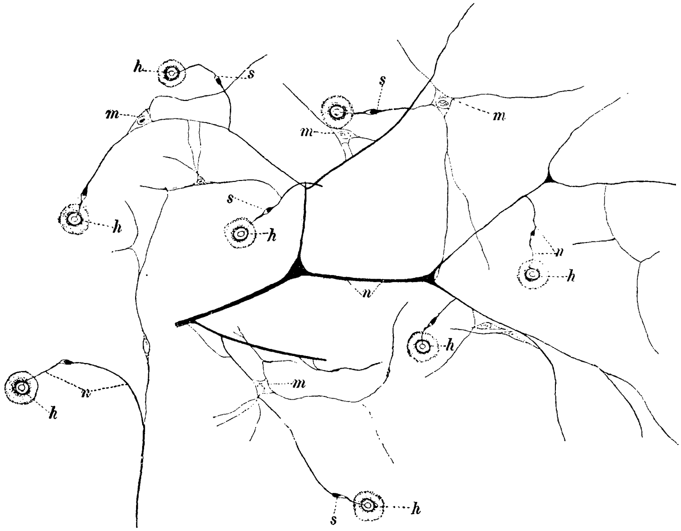

Fig. 5. — Surface view of subhypodermal nerves and cells from the silkworm (*Bombyx mori*). Bases of hairs also shown. Methylen blue.

Retzius ('95), in Astacus, by means of the methylen blue method, traced the nerve to the base of the hair. This attracted the attention of Bethe ('96), who investigated this point and found two sorts of hairs in Astacus, one as described by Retzius, in which the cavity of the hair was shut off at its base by chitin, and the other having its cavity freely open at the base. In the closed hair a nerve fiber was seen to stop at the base of the hair, but in the open hair it was continued a short distance into the shaft, and he suggests that probably this fiber goes nearer the tip than was observed in the specimens.

It was only by means of sections that it was possible to trace the nerve in the cavity of the hair, and I found it very difficult to obtain successful preparations. In the silkworm nerves were traced to the hairs by means of sections, which showed the nerves passing between the hypodermal cells, past the gland cell, or trichogen cell, without any branches, and often as far as the collar of the hair. In a few cases the nerves were traced a short distance into the shaft; but they appeared to end not far from the base of the hair on the side of the lumen (Fig. 7). Either in the hair or just below it a rather large

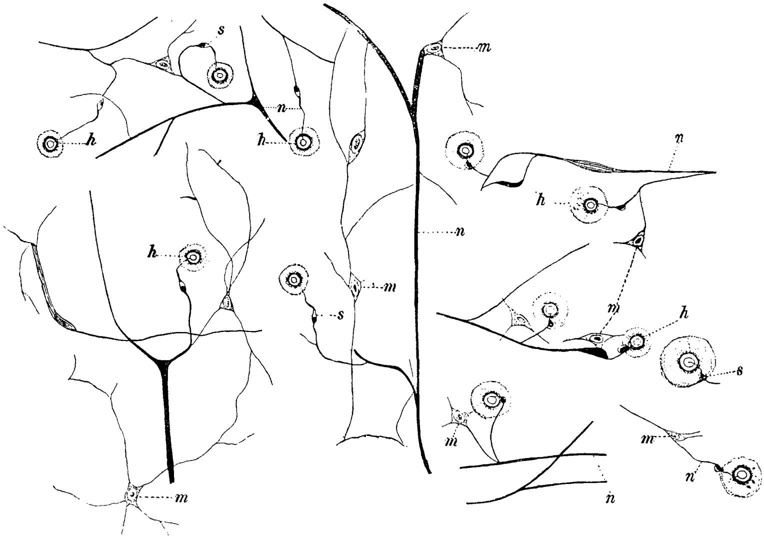

FIG. 6. — The figure in the center and those at the left are surface views of subhypodermal nerves and cells from the silkworm: the bases of the hairs are also shown. The figures at the right are the same from the myron sphinx (*Ampelophaga myron*). Methylen blue.

swelling of the nerve was usually seen; this is possibly an artifact. In a few cases nerves were traced perhaps one-half the length of the cavity. In these cases there was a swelling of the nerve just before its apparent termination (Fig. 7).

I found no evidence to indicate nerves ending in gland cells or trichogen cells by such branches as have been described and figured by Blanc ('90), but in every case the very fine nerve termination could be traced up past the hypodermal cell layer with no branches.

SUBHYPODERMAL NERVE PLEXUS.

Villanes ('81), in insects, figures a subhypodermal nerve plexus made up of multipolar nerve cells. In '93 Rina Monti, also working on insects, described a similar plexus, and in '95 Bethe described similar structures in Crustacea. Nemec ('96), in isopods, and Holmgren ('96), in a sphinx-moth larva, show multipolar networks of subhypodermal cells. All the work thus far was by means of methylen blue or ordinary methods, and because of the apparent antagonism with the neuron theory much attention was directed to this subepithelial plexus, and doubts were raised as to the nervous nature of these cells. In 1898 Schreiber, who had already in 1897 together with Nusbaum published a paper on the peripheral nervous system of Crustacea showing these multipolar cell plexuses, published another short paper showing these cells demonstrated by means of a modified Golgi method, and at the close of his article draws the following conclusions:

1. An identical methylen blue staining of the subepithelial multi- and bi-polar nerve cells.
2. Like staining of both forms of cells by the Golgi method.
3. True connections of the nerve cells with nerves.

A few months later Holmgren confirms, on the whole, Schreiber's results, but speaks of many-branched subhypodermal cells, as described by Bethe in Crustacea, and probably confused by Nusbaum, Schreiber, and other writers on Crustacea with multipolar nerve cells. Holmgren distinguishes these cells from the true multipolar nerve cells of Crustacea, regarding them as many-branched mesenchymatous cells. In lepidopterous larvæ Holmgren states that there are no mesenchymatous cells like those in Crustacea which one would confuse with nerve cells.

In 1897 and 1898 Duboscq criticises the work of many previous workers upon multipolar subhypodermal nerve cells and states as his opinion that the bipolar nerve cell is the only true nerve cell in the hypodermis of arthropods, and that there is no subepithelial plexus. Although much of the criticism of a subepithelial plexus by Duboscq is very just, it seems to me that simply calling all such structures so described connective tissue is hardly justified when we look over the works of numerous observers. It may in part be true, as Holmgren points out, that much which has been described, especially in Crustacea, may come under the head of mesenchyma, but do we not have multipolar nerve cells as well?

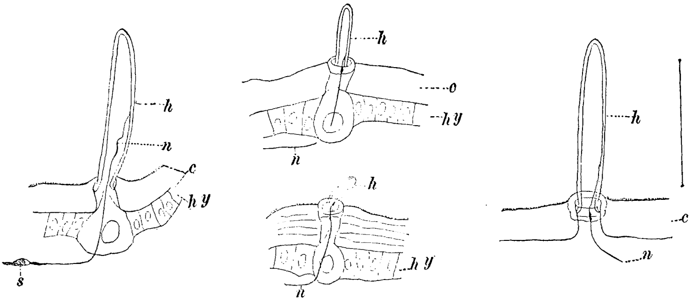

Fig. 7. — Sections through body sense hairs of the silkworm showing the nerve terminations. Methylen blue.

The occurrence of evidently multipolar nerve cells together with bipolar nerve cells and fibers I found to be very constant in lepidopterous larvæ (Fig. 6). The nucleus of these multipolar cells was a very well marked, clear area occupying a large part of the center of the cell; in the center of this clear area was a darker staining portion, possibly the nucleolus. These cells with their many fine branches always take a paler blue stain than the other nervous structures in the skin. The very fine branches of these multipolar cells run out long distances, and in the most successful preparations may be seen to join with similar branches from other multipolar cells and with other nerves. In some cases, as shown in Figs. 5-6, branches from these went directly to bipolar nerve cells or to large nerve trunks. These cells are always either in series with at least one bipolar nerve cell (Fig. 6) or have some of their branches joining the nerve trunk of the bipolar cell, or they are not far from one of these sensory cells. Often it was seen that these cells occupied a position closer to the hypodermal cells than other nervous tissues, and sometimes large nerve trunks would end bluntly, and under the ends of such trunks would be found a multipolar cell, perhaps giving one of its branches to a bipolar nerve cell (Fig. 6).

These cells were best observed in the silkworm and in the myron sphinx larva, but they were also seen in Pieris, Datana, Papilio, and practically in all forms studied. Whether these multipolar cells are nervous tissue or not cannot be fully decided as yet, but although they differ somewhat in position and staining qualities from other undoubted nerve cells, they have many characteristics which favor their being regarded as nervous tissue.

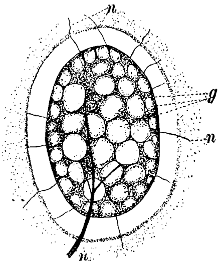

FIG. 8. — Inner face of body wall of tiger-moth larva tubercle, showing nerves going up into the elevation and breaking up among the large cells at the bases of the hairs. (× 22.) Methylen blue.

Aside from a network of multipolar cells with their processes another sort of plexus was observed. In tiger-moth larvæ the hairs are on little knoblike elevations. After injection and staining of nerve fibers there are found to go to each of these hair tubercles a large nerve, which, after entering the elevation, may be seen to break up into branches (Fig. 8), and in sections it may be seen that these branches break up still finer and each subdivision goes to a bipolar cell connected with a hair. Now, besides these larger nerve trunks, smaller ones are also seen entering the elevations, and often in successful preparations near the edge of the hair tubercles there may be seen a very complex network of apparent nerve fibers with many swellings, as shown, much enlarged, in Fig. 9. This network is apparently entirely without cellular elements and is at the same time a part of the nervous system. These networks in tiger-moth larvæ were only observed near the hair tubercles; in the silkworm a much less marked network of large and small fibers was occasionally found.

It is hard to say whether this network is truly a part of the nervous system or not; but in any case these networks are not at all like the multipolar cells just described, no nuclei or cells being recognized, but they are well stained with methylen blue and join undoubted nerves.

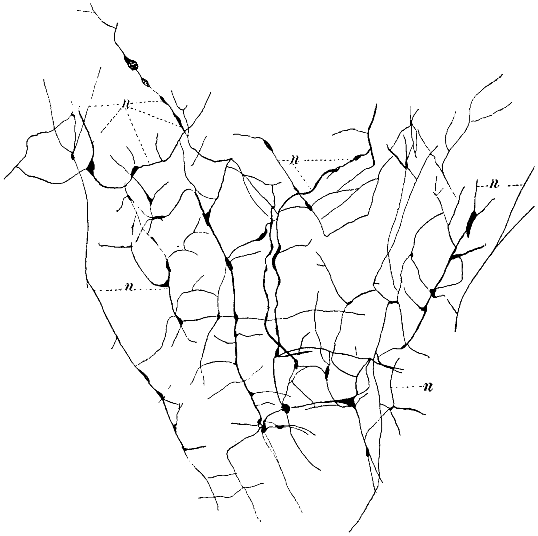

Fig. 9. — Nerve plexus from edge of hair tubercle of tiger-moth larva, much enlarged. Methylen blue.

Central Ending of Sensory Nerves.

It was not the purpose of this investigation to make a study of the central nervous system, but as it became necessary to trace the nerve fibers to the ganglia, several interesting conditions were noticed which have a more or less direct bearing upon the previous work; a few of these will be spoken of, although it is realized that no complete discussion can be given without considerable further study, and consequently further investigations will probably bring out more complex relations than here portrayed.

On each side of the abdominal ganglia of Pieris there are two large branches or nerve trunks (Fig. 10). The more cephalic of these comes from bipolar nerve cells at the bases of hairs, and the other more caudal branch goes to muscles; so, as nearly as could be determined, the cephalic trunks are sensory and the caudal ones motor. There may have been a few motor nerves in the cephalic trunk and sensory nerves in the caudal one, but if there were such, they were inconspicuous and not noted in the examination of numerous specimens; so for the present, at least, the more cephalic branch may be regarded as a sensory branch.

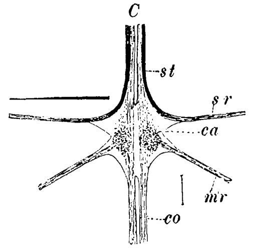

FIG. 10. — Abdominal ganglion from Pieris. Methylen blue.

This sensory branch upon entering the ganglion seems to run as a distinct tract cephalad without sending branches to the central cell area of the ganglion. This tract runs cephalad for some distance along the outside of the connective and is finally lost sight of. The course of the motor nerve is quite different; its fibers seem to come directly from the central cell area of either side of the ganglion. Aside from the fibers just described, there are nerve fibers which may be seen to run through the ganglion longitudinally; these take a lighter stain. They run along the connectives and are just inside the sensory tracts.

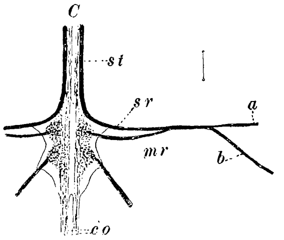

FIG. 11. — Abdominal ganglion from Io caterpillar (*Automeris io*). *a*, from hairs; *b*, to muscles.

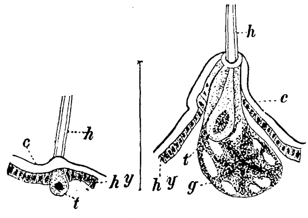

FIG. 12. — Small and large hairs from *Pieris rapæ*.

Variations in the number and position of the nerve trunks from the ganglion occur in different species. In Io and in a tiger moth the same sensory tract may be noted, but part of the sensory trunk upon entering the ganglion leaves the sensory tract and enters the cell area (Fig. 11), but on tracing the nerve to the periphery it is found that part of the fibers of the more cephalic nerve come from the muscles, and so the nerve may be regarded as a mixed nerve, showing why some of its fibers do not follow the sensory tract.

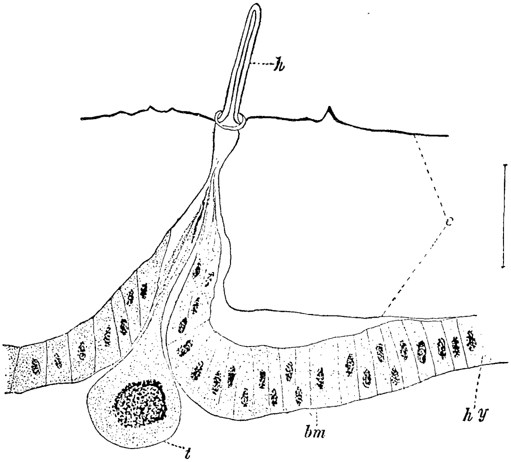

FIG. 13. — Section of hair from *Sphinx chersis.*

In lepidopterous larvæ the two sides of the ganglia seemed to be separate, possibly because of imperfect methylen blue stain. In Coryalis larva fibers were seen to cross from side to side.

GENERAL RESULTS.

In the lepidopterous larvæ examined two kinds of body sense hairs were found: first, *simple hairs*, those having a single enlarged hypodermal cell at the base (Fig. 12); and, second, *glandular hairs*, or those having two rather large modified hypodermal cells (Fig. 12). In the latter case the smaller cell is probably the trichogen cell, and the other a glandular cell of some sort. As these figures were drawn from specimens prepared in the ordinary way, the nerves are not shown.

Examples of simple hairs are represented by Figs. 13–18. The insects from which these figures were drawn are indicated in the explanations of the plates. Glandular hairs are represented by Figs. 12 and 19.

In all species examined both simple hairs and glandular hairs were found to be supplied with a bipolar sensory nerve cell and fiber. Sometimes, as in Pieris and Datana, there are two quite distinct kinds of hairs, large and small. In this case the large hairs are supplied by large bipolar nerve cells, and the small hairs by small ones (Fig. 20).

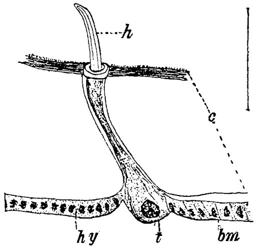

FIG. 14. — Section of hair from body surface of *Thyreus abboti.*

In tiger moths and tussock moths the hairs differ somewhat from those in other forms; here the single hairs of other lepidopterous larvæ are represented by bunches of hairs clustered together on tubercles. Each tubercle is supplied by one or more large nerve trunks, which break up on entering the tubercle. A bipolar nerve cell from each hair in this case is harder to determine absolutely; but as some of the hairs were found to have such nervation, probably all do, for all are of the same kind. The structure of these hairs differs somewhat from those already described in the form and shape of the cells, these sometimes being hollow or saclike with radiating nuclei (Fig. 2). The base of the hairs also presents variations, as shown in Fig. 2; here the chitinous base of the hair seems to extend down below the level of the cuticle. In a section through the base of a hair of Notolophus (Fig. 21) the opening of the hair is seen to be nearly closed in two places by strong processes of chitin, and sections taken just one side of the middle line show apparently a closed hair, indicating how small the opening is in the base of the hair.

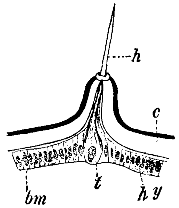

FIG. 15. — Section of hair of *Basilarchia archippus.*

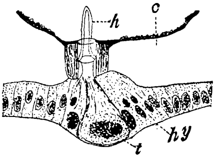

FIG. 16. — Hair from *Samia cecropia.*

All the hairs examined in lepidopterous larvæ were open and undoubtedly sensory, that is, supplied with bipolar sense cells.

Differing from the hairs just described, there are distributed over the surface of the body of the larva of the Io moth spine-like clusters, prolongations of the body wall (Fig. 22); most of these spines are tipped with short, strong, chitinized caps, and a few with long, slender, hairlike processes. These spines when touched to the tender surface of the hands produce swellings which are slightly painful. Numerous specimens stained by methylen blue demonstrated fine nerves running into these spinous processes and extending almost to the tips, but no bipolar nerve cells were demonstrated. Evidently here we have glandular hairs, but not sensory hairs; however, in the same specimens there were found hairs of the usual type, much smaller than these processes of the body wall or spines; these true hairs were located both on the bases of the spines and upon the body wall between the spine clusters (Fig. 22, *h*). No difficulty was experienced in demonstrating a bipolar nerve cell at the base of each of these true hairs.

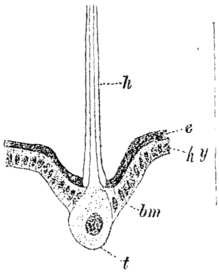

FIG. 17.—Simple hair from *Chisiocampa americana*.

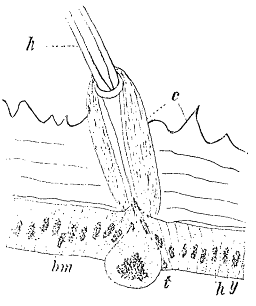

FIG. 18.—Silver-spotted skipper (*Epargyreus tityrus*).

To summarize briefly: all lepidopterous larvæ studied have their bodies clothed with hairs, and all the hairs are sensory, having a bipolar nerve cell at their base and supplied with a minute nerve fiber, with the possible exception of the poison spines of Io caterpillars.

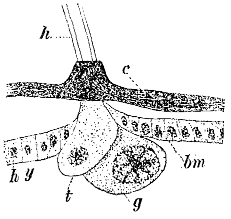

FIG. 19.—Large, probably glandular hair from Chisiocampa.

To carry the generalizations a little further, the following observations are useful. In the larvæ of May beetles the hairs of the body surface are supplied with bipolar nerve cells (Fig. 23), and in Orthoptera, as already spoken of by Duboscq ('97), the hairs have a bipolar sense cell at their base. In the larva of Corydalis, bipolar nerve cells with their fibers supply each of the numerous little, black, scalelike hairs which so thickly cover the body ; large hairs have larger bipolar nerve cells (Fig. 3).

Günther ('01) shows scales of a lepidopterous wing with nerve cells at the base of both simple and glandular scales, probably a similar result to that just described in Corydalis.

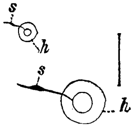

FIG. 20.

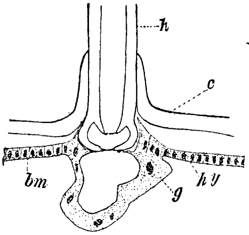

FIG. 21.

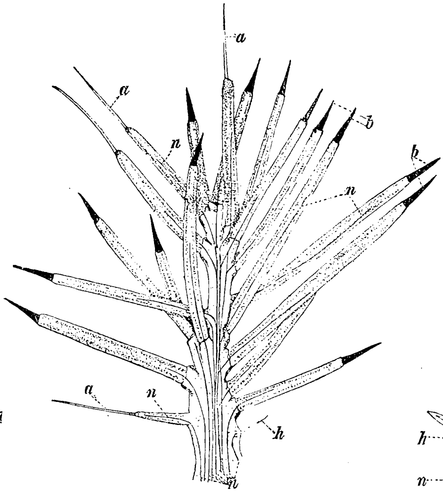

FIG. 22.

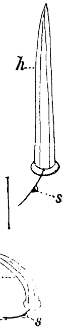

FIG. 23.

FIG. 20. — Bases of large and small hairs from Datana, showing their bipolar nerve cells. Methylen blue.

FIG. 21. — Section through center of hair of *Notolophus leucostigma*.

FIG. 22. — Cluster of spines from Io. (× 17.) Methylen blue. *a*, hairlike spine; *b*, usual type of spine.

FIG. 23. — Large and small hairs from beetle larva with their sense cells and nerves. Methylen blue.

SUMMARY.

1. Lepidopterous larvæ are clothed with hollow hairs, each of which is supplied by a bipolar nerve cell, a process of which penetrates a short distance into the hair and probably terminates before reaching the tip.

2. In most species all body hairs are sensory; large hairs are supplied by large bipolar nerve cells, and small ones by smaller bipolar cells.

3. Under the hypodermis of caterpillars there is a system of multipolar cells more or less intimately connected with nerve

cells and fibers which (*a*) stain lighter than the larger nerves and (*b*) are closer to the hypodermis than the other cells and fibers.

4. Nerves from bipolar sensory nerve cells go to the central nervous system, run to the ganglia, leaving at once to follow on the outside of the connectives cephalad, forming a well-marked sensory tract. Motor nerves — those that go to muscles — seem to come directly from the central cell areas of the ganglia.

5. Almost the only sensory termination of nerves on the body of insects is by means of hairs.

I wish to make my very sincere acknowledgments to Professor Comstock and the Department of Entomology for much invaluable aid in the preparation of this paper.

BIBLIOGRAPHY.

'96 BETHE ALB. Ein Beitrag zur Kenntniss des peripheren Nervensystems von Asticus. *Anat. Anz.* 1896.

'97 BETHE ALB. Das Nervensystem von Carcinus menas. *Arch. f. Mikr. Anat.* 1897.

'90 BLANC, M. L. La tête du Bombyx mori à l'état larvaire. Extrait du volume des travaux du laboratoire d'études de la soie. Lyons, 1889–90.

'97 DUBOSCQ, O. Sur la terminaison des nerfs sensitifs des chilopods. *Ann. de l'Univ. de Grenoble.* 1897.

'97 DUBOSCQ, O. Sur le système nerveux sensitif des tracheates (orthopteres, chilopods). *Arch. de Zool. Exp. et Génér.* 1897.

'98 DUBOSCQ, O. Recherches sur les chilopods. *Arch. de Zool. Exp. et Génér.* Sér. 9, tome vi. 1898.

'01 GÜNTHER, K. Ueber Nervenendigungen auf dem Schmetterlingsflügel. *Zoöl. Jahrb.* Bd. xiv. 1 Taf. 1901.

'80 HAUSER, G. Physiologische und histologische Untersuchungen über das Geruchsorgan der Insecten.

'95 HOLMGREN, E. Studier öfver hudens och koertebart hudorg. morfolog. hos skand. mikrolepidopterlarven. *K. Svenska Vetensk.-Akad. Handlingar.* 1895.

'95 HOLMGREN, E. Zur Kenntniss des Hautnervensystems der Artropoden. *Anat. Anz.* 1895.

'93 Holmgren, E. Zum Aufsatze W. Schreibers "Noch ein Wort." *Anat. Anz.* 1898.

'81 Kunckel et Gajagnaire. Rapport du cylindre-axe et des cellules nerveuses périphériques avec les organs des sens chez les insects. *C. R. Aud. Se.* 1881.

'51 Leydig, F. Anatomisches über Corethra plumicomis. *Zeitschr. f. wiss. Zool.* 1851.

'93 Monti, Rina. Ricesche microscopische sul sistema nervoso degli insetti. *Boll. scient.* 1893–94.

'96 Nemec, Bohumil. Zur Kenntniss des peripheren Nervensystems einiger Crustaceen. *Anat. Anz.* 1896.

'97 Nusbaum and Schreiber. Beitrag zur Kenntniss des peripherischen Nervensystems bei den Crustaceen. *Biol. Centralbl.* 1897.

'91 Rath, O. Vom. Zur Kenntniss der Hautsinnesorgane der Crustaceen. *Zool. Anz.* 1891.

'92 Rath, O. Vom. Ueber die von C. Claus beschriebene Nervenendigungen in den Sinneshaaren der Crustaceen. *Zool. Anz.* 1892.

'94 Rath, O. Vom. Ueber die Nervenendigungen der Hautsinnesorgane der Arthropoden nach Behandlung mit der Methylenblau und Cromsilbermethode. *Berichte der natur. Gesellsch. zu Freiburg.* 1894.

'96 Rath, O. Vom. Zur Kenntniss der Hautsinnesorgane des sensiblen Nervensystems der Arthropoden. *Zeitschr. f. wiss. Zool.* 1896.

'90 Retzius, G. Zur Kenntniss des Nervensystems der Crustaceen. *Biol. Unt.* N.F. 1896.

'92 Retzius, G. Ueber die Nerven-Prinzipien in der Lehre von der Einrichtung des sensiblen Nervensystems. *Biol. Unt.* N.F. 1892.

'95 Retzius, G. Das sensible Nervensystem der Crustaceen. *Biol. Unt.* N.F. 1895.

'98 Schreiber, W. Noch ein Wort über das peripherische sensible Nervensystem bei den Crustaceen. *Anat. Anz.* 1898.

'81 Villanes. Sur les terminations nerveuses sensitives dans la peau de quelques insects. *C. R. Acad. Sc.*

'83 Villanes. Recherches sur l'histologie des insects et sur les phénomènes histologiques qui accompagnent le développement postembryonnaire de ces animaux. *Th. Pairs.* 1883.

ABREVIATIONS USED IN FIGURES.

bm = basement membrane.
C = cephalic direction.
c = cuticle and cuticular thickenings.
ca = central cell area.
g = gland cell.
h = hair.
hy = hypodermis.
mr = motor root.
s = sensory cell.
st = sensory tract.
co = connective.
m = multipolar cell.
n = nerve.
sr = sensory root.
t = trichogen cell.

Lines near drawings indicate $\frac{1}{10}$ mm.